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ORIENTATION AND JUMPING BEHAVIOR IN THE GOBIID FISH *BATHYGOBIUS SOPORATOR*¹

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Investigators at the Lerner Marine Laboratory, Bimini, British West Indies, had described to the writer a remarkable habit of the tide-pool-dwelling gobiid fish *Bathygobius soporator* (Cuvier and Valenciennes), namely, their ability to leap effectively from one pool to another when, because of the high sloping rims of the rocky pools, it is not possible for them to see the second pool at the onset of the leap. As a basis for orientation it has been suggested that the goby is able to adjust to the general features of the pools. Such an orientation might develop especially under the influence of visual stimulation when the pools are flooded at high tide and the fish are moving about. Although numerous articles have appeared on various phases of the life history of this species (Beebe, 1931; Longley and Hildebrand, 1941; Breder, 1943, 1948, 1950; Tavalga, 1950), to the writer's knowledge no published account of the jumping behavior, or mention of it, has appeared as yet. The problem has an additional interest in that the same species, *Bathygobius soporator*, is found along certain sandy-beach areas far removed from any tide-pool situations. The coloration pattern of this species is highly variable and changes rapidly. Tavalga (1950) shows that the tide-pool

¹ This study was conducted at the Lerner Marine Laboratory of the American Museum of Natural History at Bimini, British West Indies.

The author wishes to express his gratitude to Dr. William N. Tavalga, who aided materially in both the planning and execution of this study, and for reading and criticizing the manuscript. Drs. T. C. Schneirla and C. M. Breder, Jr., also read the manuscript and made many helpful suggestions.

populations differ from the beach populations in the types of pattern displayed most frequently both in the field and under standardized laboratory conditions of light and background. These differences, which are closely correlated with their habitat background, are maintained in mixed groups for periods of up to two weeks and are also observed in the fright reaction of individuals. Tavalga suggests two possible explanations as to the origin of these differences. One is that adaptational conditioned responses are established during early life. The other is that the differences are genetic in nature, having accumulated as a result of selective environmental forces, and hence these populations may be in the earliest phases of speciation. Since there are some suggestions that the jumping behavior may also differ, an investigation of this behavior may then throw further light on the ecological status of these populations.

During the summer of 1949, the writer had the opportunity of conducting at Bimini a preliminary field study of this behavior as background for a more extensive field and laboratory investigation planned for 1950.

Most of the observations were carried out at Entrance Point, a limestone outcrop forming the southernmost tip of North Bimini Island. Subsidiary observations were made at Turtle Rock, an uninhabited reef about 1 mile off South Bimini, and at a small rocky ledge northeast of the laboratory designated as Hickman's Ledge. Except where otherwise indicated, all of the observations were made during two or three hours of low tide in daylight. The first records were taken during July, but the bulk of the data was collected in August of 1949. The tide pools all varied in size, shape, water content, flora, and fauna. The ones found to be most useful for this study were about 1 meter in diameter, with 5 to 10 cm. of water, and contained no fish other than *B. soporator*.

Our first problem was to determine under what conditions the gobies would jump. It was noticed that when one approached certain pools, particularly along the edge of the open water, fish about the size of a goby might leap out, often into the open water. Where identification was possible, these proved to be another regular tide-pool inhabitant, the blenny *Salarichthys textilis* (Quoy and Gaimard). It is possible, however, that a few of the unidentified fish were gobies. Generally, the gobies did not jump unless the water was actively agitated, or unless they were actually pursued and prodded by the observer. Even then they did not jump if,

instead, they could swim into a crevice of sufficient magnitude to afford protection. Since many of the pools contained a large number of such crevices, such pools had to be abandoned in favor of a smaller number with a solid base, or with a limited number of crevices that could be charted and plugged.

As far as could be determined, the leaps always started with the fish resting on the substratum of the pool. They would face in the direction of the pool towards which they were about to jump and would assume a characteristic pose with the body curved to one side. Then with a sudden snap, which was too rapid to be seen clearly, they would shoot through the surface of the water and fly through the air to the adjacent pool.

A total of 51 jumps by 18 fish was observed during the two months. The tide pool in which a goby was first discovered was arbitrarily designated as the home pool. Hence most of the jumps were from these home pools. The fact that the same gobies seemed to be in these pools day after day, together with Beebe's (1931) observation that transplanted gobies will return to the original pool, suggests that, in many cases at least, our designations represent the home pool in the strict sense of the term.

PROTOCOLS

1. Entrance Point, Location II (fig. 1), 7/20/49, low tide. A medium-sized goby (about 4 cm. long) was prevented from entering the crevice area, and while being pursued it leaped from the home pool to pool B and immediately headed for another crevice. The jumping point was not the lowest rim of the home pool.

2. Hickman's Ledge, Location X, 8/3/49, 10 A.M., low tide. A 3-cm. goby was chased into an adjacent, connected pool, B, where it headed immediately for crevice "a." Five minutes later it came out of crevice "a" and swam under a rock in the home pool. We plugged crevice "a" with algae and again chased the goby from under the rock. It immediately headed for crevice "a," nosed the algae for several minutes, and finally headed for an adjacent shallow crevice, "b." Chased out of crevice "b" it headed for the home pool, but its connection with pool B was blocked by the observer's arms. It nosed the block for several minutes and then headed back to crevice "b," which in the meanwhile was also blocked. Upon further prodding the goby again headed for the block between the home pool and pool B. After nosing the block for several minutes, it swam back and forth between the block and

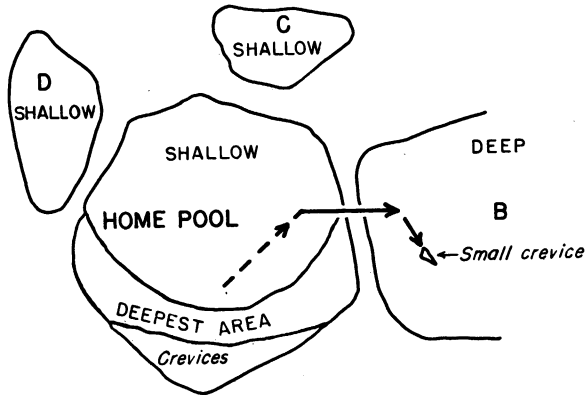


FIG. 1. Schematic outline of the pools, paths, and jumps taken by the gobies in location II. $\times .07$ (approximate).

In figures 1-3, 5, 7-12 the heavy broken lines represent the paths taken by the fish while swimming; the heavy solid lines indicate jumps; the heavy dotted lines represent skimming or skipping over wet rocks. The letters refer to specific details in the protocols.

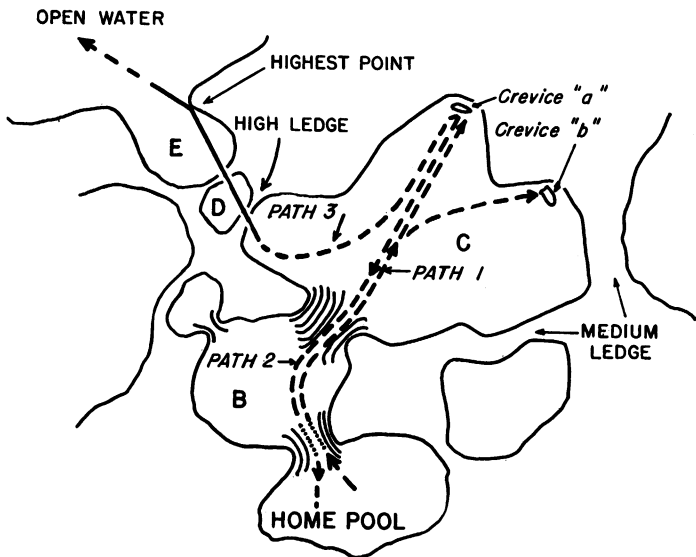


FIG. 2. Schematic outline of the pools, paths, and jumps in location XI. $\times .07$ (approximate).

the stopped crevices. Further prodding indicated that the fish was exhausted, and it was then collected for other experiments. This goby could not be made to jump.

3. Hickman's Ledge, Location XI (fig. 2), 8/3/49, 11 A.M., low tide. A goby 3 cm. in length followed path 1 through a series

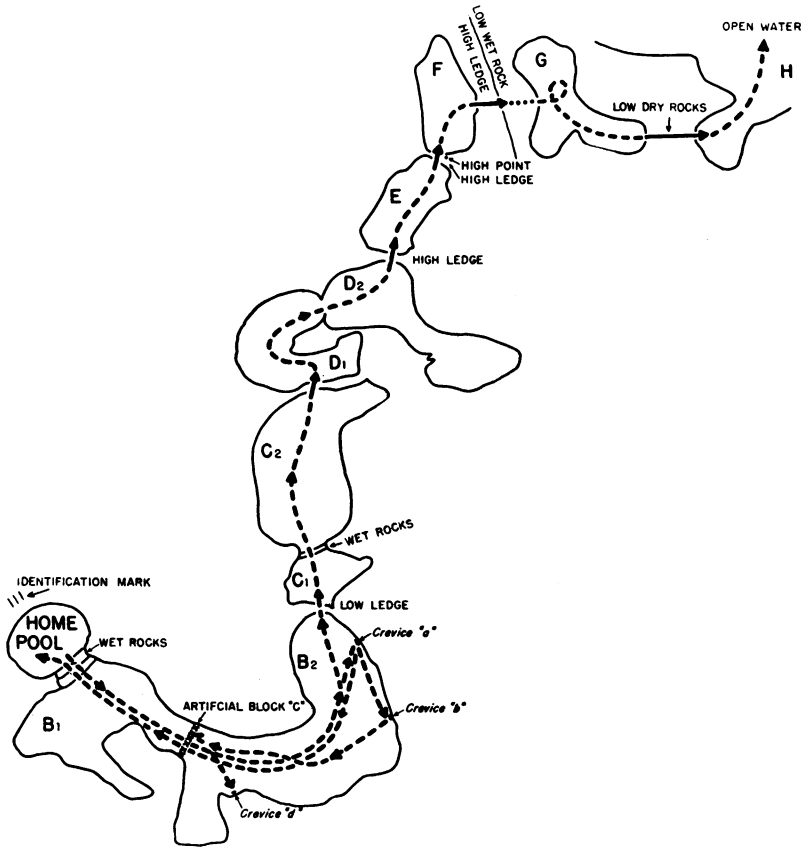


FIG. 3. Schematic outline of the pools, paths, and jumps in location III. X .015 (approximate).

of three pools connected by narrow passages just at water level. It went directly to crevice "a." When prodded out of crevice "a" it followed path 2 to the home pool. When disturbed again, this goby again followed path 1 to crevice "a." The second time it was forced out of crevice "a," it moved along path 3, leaped over a ledge about 5 cm. high, cleared pool D, struck a high rock

jutting into pool E, landed in this pool, which was connected with the sea, and escaped.

A second goby of similar size when chased out of the home pool followed leisurely along path 1 and after much prodding entered crevice "b."

4. Entrance Point, Location III (figs. 3 and 4), 9/7/49, 2 P.M., low tide. Four medium-sized gobies were found in a conch

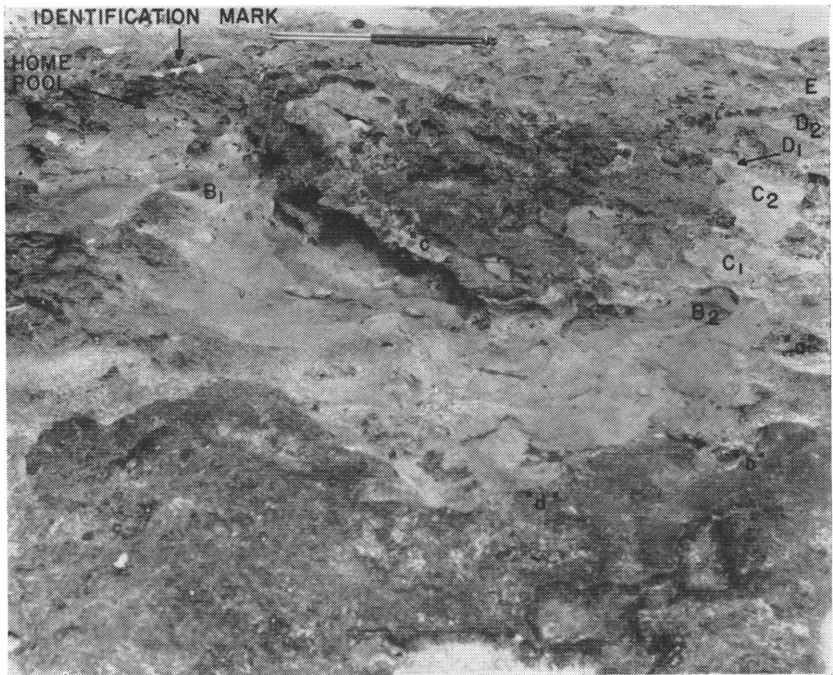


FIG. 4. Photograph of the home pool and adjacent area of location III.

shell in the home pool. When chased, the first two swam immediately to crevice "a"; the third made a short stop in the middle of pool B₂ and then swam to crevice "a." A few minutes later, the fourth goby also headed directly to crevice "a." All four gobies were then prodded out of crevice "a." Two immediately swam back to the home pool. The other two swam directly to crevice "b."

Crevice "a" was now blocked by being stuffed with algae and, when the two gobies in "b" were disturbed, one of them swam to

crevice "a" (blocked), nosed the blockade for several minutes, and then returned to the home pool. A block "c" was then established in the passageway between pools B₁ and B₂, and the fourth goby, when chased out of crevice "b," swam to the block, nosed it, and swam unceasingly from one end of the barricade to the other for a considerable length of time. With further prodding it swam to several other crevices that had been spotted and blocked prior to the start of the observation. Observations on this goby were discontinued because of distinct signs of exhaustion.

The artificial block "c" was then removed. When the three gobies that had returned to the home pool were again pursued, one of them swam through pools B₁ and B₂, leaped over a low ledge to pool C₁ and over wet rock to pool C₂. When prodded again, it jumped to pool D₁, swam to D₂, jumped to E, and leaped again into pool F over the highest part of the wall surrounding pool E. When disturbed once more, it jumped, fell far short of the mark, and then by a series of short jumps it skimmed over the intervening moist rocks to G, made a loop as it swam through G, made another long jump to H, which was connected with the open water, and escaped. The total distance traversed by this goby from the home pool to pool H was about 9.5 meters. The lengths of the jumps were as follows:

B ₂ to C ₁	6 cm.
C ₂ to D ₁	5 cm.
D ₂ to E	30 cm.
E to F	15 cm.
F to G	38 cm.
G to H	35 cm.

The second goby when disturbed in the home pool swam to crevice "d."

The third goby swam through B₁ and B₂, jumped to C₁, swam to the opposite end of C₂ and jumped to D₁, swam to D₂ and jumped towards E. However, it landed on the rocks short of the pool. It made a few short hops and finally landed in the water of pool E, where it immediately swam to the opposite end and made the high jump to F. In this jump, the goby struck a glancing blow against a projecting ledge and fell into the pool. This goby refused to jump farther and was prodded until exhausted.

A medium-sized goby taken from a pool about 18 meters away was placed in the home pool of location III. When prodded it failed to make even the simplest jump over the wet rocks to B₁.

Instead it swam into shallow and totally inadequate crevices. It was prodded until exhausted.

Two gobies from pools about 30 meters away reacted in a similar fashion.

A goby from a pool only 9 meters away failed to jump and was prodded until exhausted.

5. Entrance Point, Location V (figs. 5 and 6), 8/8/49, 2 P.M., low tide. Several gobies were found under a large red stone. By

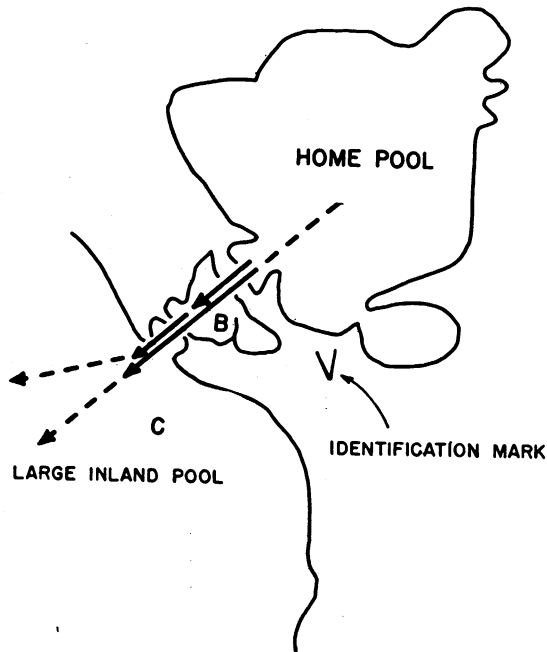


FIG. 5. Schematic outline of the pools, paths, and jumps in location V. $\times .03$ (approximate).

creating only a slight disturbance, two 2.5-cm. gobies were stimulated to jump from their home pool to pool C. Two smaller gobies (about 2 cm.) leaped from the home pool to B and then to C. Pool C is a very large shallow pool at the same level as the home pool, but inland from the latter.

A large goby in the home pool of location VI (1.5 meters away) leaped over two barriers and was caught in a net. Transplanted to the home pool of V, it failed to jump despite continuous prod-

ding. Because of peculiar markings, this goby was left in the home pool of V.

8/9/49, 2:30 P.M., low tide. The goby with the peculiar marking could not be seen in the home pool.

8/22/49, 3 P.M., low tide. Almost all of the water was siphoned out of the home pool and an equal quantity of fresh water was added. One medium-sized goby jumped directly from the home

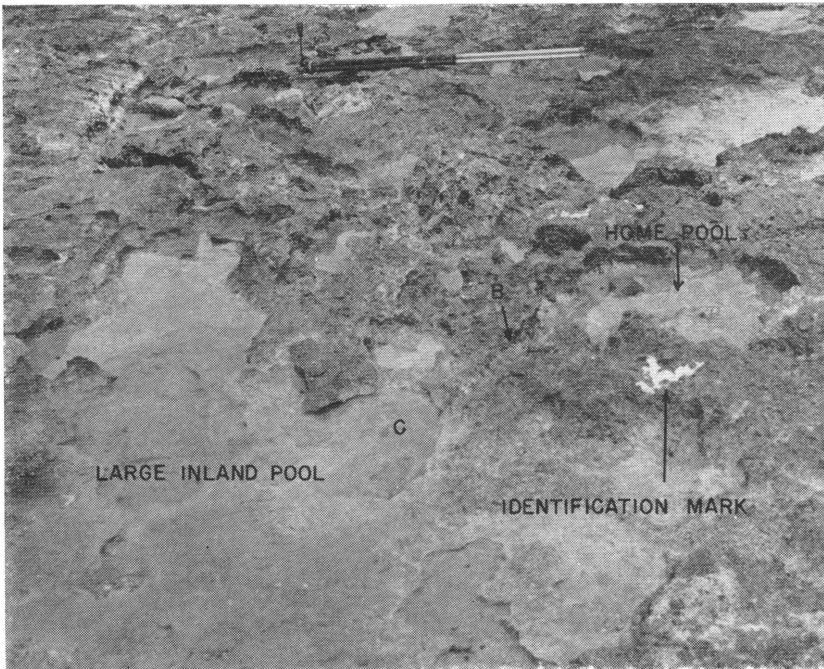


FIG. 6. Photograph of location V.

pool to C. Several others remained under the red stone and did not jump.

8/23/49, 3:30 P.M., low tide. Water temperature of home pool was 37.5°C .; in pool C, 39.5°C .

8/24/49, 11 A.M., tide ebbing for almost one hour. Although at high tide the entire reef is usually inundated, with the tide ebbing for one hour the pools of location V were already separated from the open water. However, a shallow layer of water connected the home pool with pools B and C. Several small and medium gobies

were seen under the red stone, and when it was lifted two gobies traversed the usual path from the home pool to C.

A goby from location IX (see below) was introduced into the home pool of location V. It swam around for a few moments and then under the red stone with the native fish. The stone was then removed, and the gobies were disturbed. The native gobies, as well as the introduced one, all took the regular path through B to C. Because of the shallow layer of water connecting the pools, jumping, if any, was slight at this time.

6. Entrance Point, Location VI (fig. 7), 8/8/49, 2 P.M., low tide. A large goby when disturbed in home pool jumped to pool

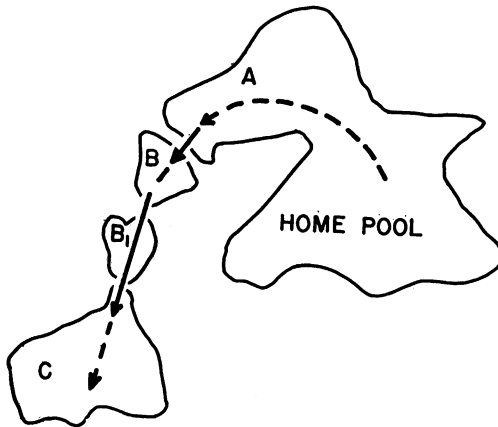


FIG. 7. Schematic outline of the pools, paths, and jumps in location VI. $\times .05$ (approximate).

B, and over pool B₁ to C. This fish was caught in a net and transferred to location V. From A to C represented a distance of about 90 cm. The jumps were as follows:

A to B	5 cm.
B to C	30 cm.

7. Entrance Point, Location I (fig. 8), 8/8/49, 3 P.M., low tide. The medium-sized gobies (4 cm.) and five small ones (2.5 cm.) were found in home pool. All of the adjacent surrounding pools were dry. After considerable prodding two of the largest gobies jumped as follows:

The first leaped to B (dry) and immediately to C (dry) and seemed headed in the direction of a dry crevice. The other

jumped to B and then to D, both of which were dry. A small goby leaped from A to F (dry) and then to C. Another medium-sized goby followed the same path. All eight fish were collected, brought to the laboratory, and placed in an aquarium.

8/22/49, 2 P.M., low tide. Two very small gobies (1.5 cm.) were found in home pool. Despite continuous prodding they did not jump. Temperature of home pool was 37.5° C.

Four of the gobies from this location that were brought to the laboratory on August 8 were now retested. They were numbered from 1 to 4. Goby No. 1 when introduced into the home pool and then prodded jumped to G (dry) and immediately to H (dry).

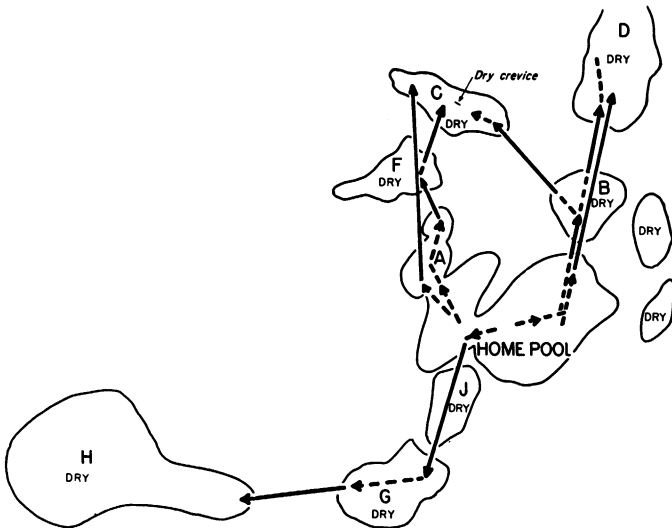


FIG. 8. Schematic outline of the pools, paths, and jumps in location I. $\times .02$ (approximate).

The jump from home pool to G measured 73 cm.; from G to H, 53 cm.

Goby No. 2 when introduced into the home pool leaped directly to D (dry) which represented a distance of 1 meter. Returned to the home pool it now jumped from A to C (dry) which was also a distance of about 1 meter. When brought back to the home pool goby No. 2 repeated the jump to D.

Goby No. 1 was returned to home pool and jumped again towards G, but landed just to the side of the dry pool, and it jumped immediately to H (dry).

Goby No. 1 jumped from home pool to F. On this day F contained a shallow layer of water (temperature 38° C.).

One of the very small gobies mentioned above jumped from the home pool to F.

Goby No. 3 jumped from A to F. Prodded at F it jumped to C.

Goby No. 4 (the smallest of the four) did not jump despite continuous prodding.

Gobies Nos. 1 to 4 were removed. Four other gobies which had been previously collected in Porgy Bay (a sandy beach area without tide pools located about 1 mile from Entrance Point) were now introduced into the home pool. None of these jumped despite continuous prodding until exhaustion. A large goby was found under a rock at the water's edge about 5 meters directly east of the home pool. When this fish was placed in the home pool, it also failed to jump. These five non-resident fish were marked by clipping their fins, and left in the home pool.

8/23/49, 9:30 A.M., high tide. All of the pools in this location were completely inundated up to the identification number cut in the rock. No gobies could be seen.

2 P.M., low tide. The five marked gobies could not be found. Two small gobies were seen. Apparently these were the same two found in the home pool yesterday at low tide. One of these jumped to J which was dry. This fish was returned to home pool. Temperature of the water in the home pool was 37° C.

8/24/49, 11 A.M., tide ebbing for about one hour. Level of water just at rim of home pool. Saw one of the young gobies but none of the transplanted ones.

12 Noon, ebbing tide. Pools C and D were draining rapidly.

3 P.M. Two small gobies (probably the same fish seen now for two consecutive days) in home pool.

8/30/49, tide flowing. Water at level of lower pool D. As a result of the hurricane of August 26, 1949, all of the pools in this location were filled with sand. This was cleared out before observations began. Two small gobies were still found in the home pool. The four resident fish originally taken from the home pool on August 8 and again on August 22 and maintained since then in the laboratory were introduced into the home pool. After some prodding No. 1 jumped to C. A wave flooded this pool, and the goby disappeared. No. 2 jumped to D and escaped to the open water. No. 3 (largest) jumped to H (dry). No. 4 failed to jump, as usual.

8. Entrance Point, Location VIII (fig. 9), 8/8/49, 3:30 P.M., low tide. Two gobies, one medium and one small, were found under a small rock in home pool. All of the water was siphoned from the pool, but the fish remained under the wet rock. When the rock was removed and the larger goby was prodded, it made a series of small leaps and eventually reached a large and higher adjacent pool and escaped.

8/22/49, 1:30 P.M., low tide. Three medium-sized gobies (about 3 cm.) were in home pool. One pound of sea salt was

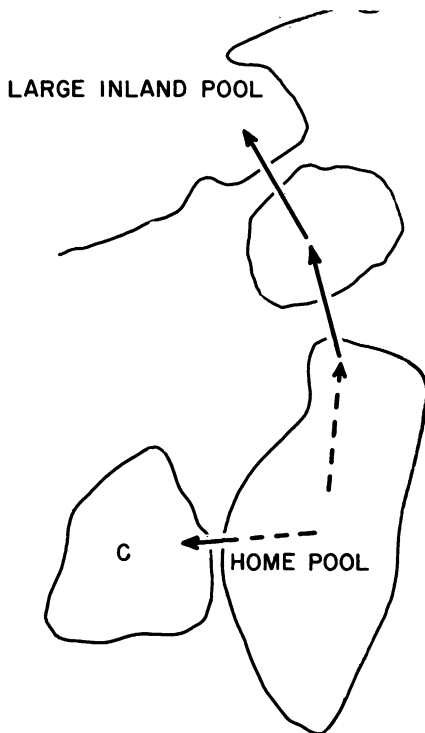


FIG. 9. Schematic outline of the pools, paths, and jumps in location VIII. $\times .05$ (approximate).

poured into the water. This dissolved gradually. After about 15 minutes the smallest of the three jumped to pool C which contained a thin layer of water at 38° C. The largest of the three jumped a few minutes later to the larger inland pool, the temperature of which was recorded as 39° C. In over one-half hour of

further observation the third goby remained in the salted pool. A sample of the water from the home pool was later assayed and found to contain 81 grams of NaCl per liter. A similar sample taken just before the salt was added contained 31 grams of NaCl per liter.¹

8/24/49. A medium-sized goby caught in location VI was transferred to the home pool of location VIII. After continuous prodding it failed to jump.

9. Entrance Point, Location VII (fig. 10), 8/22/49, 2 P.M., low tide. A medium-sized goby leaped over a barrier 10 cm. high from

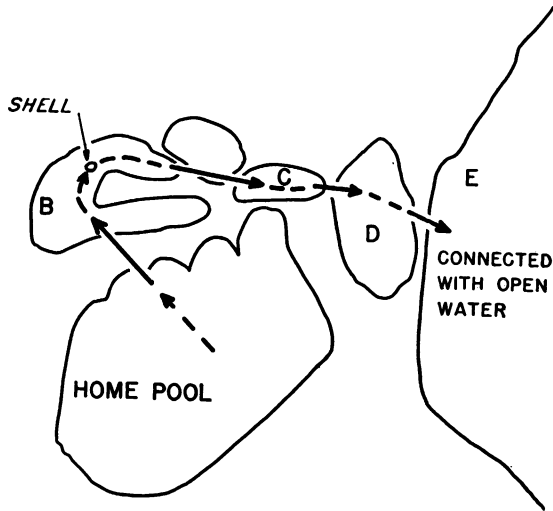


FIG. 10. Schematic outline of the pools, paths, and jumps in location VII. $\times .06$ (approximate).

the home pool to B and hid under a conch shell. This represented a jump of 15 cm. Pool B was higher than the home pool.

8/24/49, 11 A.M., tide ebbing for one hour. Conch shell in pool B was lifted and a large goby swam out, jumped immediately to C, then to pool D, and finally escaped by jumping to E, which was connected with the open water.

A medium-sized goby captured in pool C of location V was marked by cutting the tail fin, and introduced into pool B of

¹ The writer wishes to thank Mrs. Evelyn S. Shaw for making these salinity determinations.

location VII. Despite continuous prodding this fish failed to jump. Captured and marked another fish in location V, pool C, and introduced it into pool B of location VII. This goby also failed to jump. At its nearest point, pool C of location V is only 90 cm. from B of location VII. Both marked gobies were left under the conch shell in this pool.

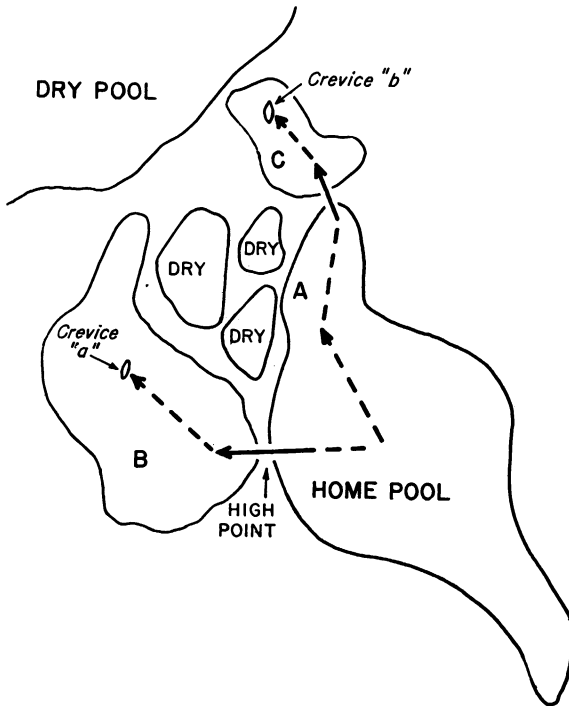


FIG. 11. Schematic outline of the pools, paths, and jumps in location XIII. $\times .1$ (approximate).

3 P.M., low tide. Both marked gobies were still under the shell. The temperature of water in B, location VII, was 37° C.

Observations were curtailed by the impending hurricane, and after the storm the two marked fish in B, location VII, were no longer there.

10. Turtle Rock, Location XII, 8/9/49, 3 P.M., low tide. A medium-sized goby was prodded and jumped to an adjacent pool and escaped into a deep crevice.

11. Turtle Rock, Location XIII (fig. 11), 8/9/49, 3 P.M., low tide. Several small gobies and one medium-sized goby were found in the home pool. When disturbed, the medium-sized goby jumped to pool B and into crevice "a." A small goby jumped from A to pool C and into crevice "b." The rim of pool B was 12 cm. above the water level of the home pool. Pool C was 8 cm. lower than the home pool.

12. Entrance Point, Location IX (fig. 12), 8/23/49, 9 A.M., two hours after high tide. A large goby in a conch shell jumped,

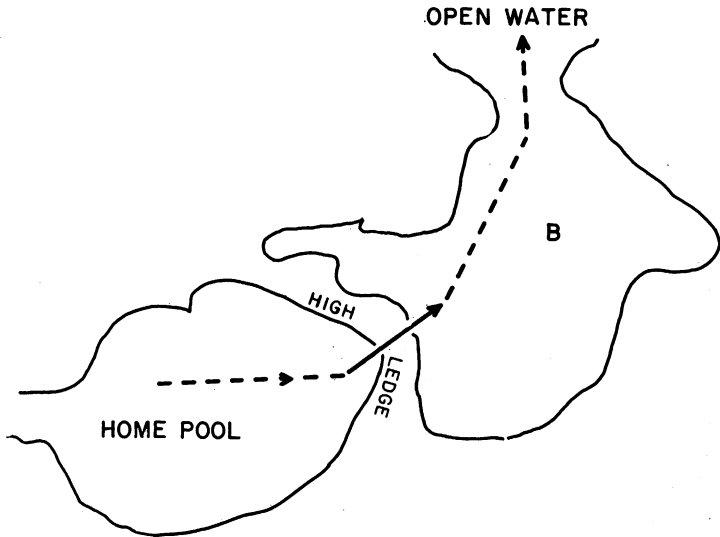


FIG. 12. Schematic outline of the pools, paths, and jumps in location IX. $\times .06$ (approximate).

when disturbed, over a wall 10 cm. high a distance of 25 cm. to pool B, which at this time was connected with the open water.

2 P.M., low tide. This goby was not seen in either the home pool or pool B.

13. Entrance Point, 8/27/49, 4 P.M. This was one day after a severe hurricane had passed almost directly over Bimini. The water was still very turbid, and in general the fish population around the island had been seriously displaced. However, gobies were seen in several tide pools, including the home pools of locations I and V.

DISCUSSION

From a consideration of the protocols the following factors can be evaluated as cues which orient the goby before it jumps:

1. While in several cases the fish jumped through the original outlet or a notch in the rim of the home pool, they were also observed to leap over high points (protocols 1, 3, 4, 9, 11, 12). Hence not all of the gobies are simply reacting to notches or similar configurations.

2. Jumps occurred in all directions, and in a few cases (protocols 7 and 13) two or more fish took totally different paths from the home pool during a single observation. Thus the position of the sun or shadows cast by the sun, so important for the orientation of ants (Brun, 1914; Schneirla, 1929), cannot be considered likely points of reference. Moreover, some of the jumps were observed on overcast days. While many of the jumps were downward and led to the sea, others were upward, away from the open water, and carried the fish to either smaller or larger pools. In almost every case except in the special conditions described in protocol 7, the fish reached situations that afforded considerable protection.

3. A trial and error learning of the jumps is conceivable but not likely. While the fish struck the rocks on a few occasions (protocols 3 and 4), serious errors were never observed except in the special case of protocol 7. Moreover, for many hours of most days the rocks surrounding the pools were hot and dry, and any such errors might well prove fatal. For trial and error learning to be successful, it would be necessary to postulate jumping practice on rainy days or during early hours of the ebb tide while the surrounding rocks were still wet. This has never been seen, but additional observations are needed.

4. There remains a fourth alternative, our original hypothesis, that the fish learn the local configurations as they swim over the pools at high tide. That is, the gobies possess an effective memory of the general topography of a specific area which they utilize when locked in their pools at low tide. The most important evidence in support of this hypothesis comes from the transfer experiments. Tested jumpers when removed from their home pools and returned at a later date, jumped when prodded (protocol 7). Thus in location I, when the fish landed on the hot sand of the dried-up pool, they were picked up by the observer and returned to the home pool. A few minutes later, when prodded, they would jump

again. In two cases this was repeated several times. It clearly shows that handling the fish does not inhibit their jumping behavior. On the other hand, fish transported from Porgy Bay, about 1 mile away (protocol 7), from distant locations on Entrance Point (protocol 4), and even from neighboring pools (protocols 4, 5, and 9) never jumped even when prodded until they were so exhausted that they could be easily picked out of the water by hand. Protocol 7 is particularly interesting because it shows that when the conditions change during low tide and the fish could not possibly have experienced these changes, then serious errors occur regularly. This protocol has one further point of interest in showing that this memory of the local topography may be retained for at least two weeks.

Further support of our hypothesis is found in the literature. Breder (1948) observed that *Bathygobius soporator* are regular (not casual or accidental) inhabitants of the tide pools, and Beebe (1931) found that individuals of this species when removed from one pool to another generally returned to the same pool. Moreover, Breder noted that the hurricane which passed close to Bimini on September 16, 1947, stripped the tide pools of all fish life except for *Bathygobius*, and this is confirmed by our observations after the hurricane of August 26, 1949, which passed almost directly over the island. In general these observations suggest a definite orientation to a specific topography.

In a series of laboratory experiments on a related gobiid fish, *Gobius minutus* Linnaeus, Goldsmith (1905, 1912, 1914) has demonstrated clearly the existence of a topographic memory and its dominance over the memory for form and color. This is mostly a visual response, but a motor component (memory of movement already effected) is not excluded. This dominance of topographic memory is manifested, according to Goldsmith, by its definiteness when site, form, and color are in conflict. Moreover, memory of site was found to be more enduring than that of color or form. A maximum of 18 days, which this investigator reports, corresponds favorably with our finding of 14 days, but it is doubtful whether in either case the upper limits have been tested. Mast (1915) observing the behavior of *Fundulus* along a sandy beach at Beaufort, North Carolina, noted that they are frequently found in temporary tide pools, but usually move out as the tide falls. However, if trapped they leave the pool on the side near the original outlet and travel overland across sand bars up to 3 meters wide

and 10 cm. high. Locomotion on land is accomplished by successive leaps which carry the fish in the right direction. Mast concludes that these fish remember the original outlet and that its sudden closing constitutes the principal stimulus causing the fish to leave the pool. In most of our observations on *Bathygobius*, crossings were accomplished by one or two direct leaps, but in one case where an area of several feet intervened, the goby fell far short of the mark, and then by a series of short successive leaps (which seemed to be well directed) it reached the next pool (protocol 4). Except for one case, where the gobies followed completely the path of the incoming and outgoing tide, the leaps did not in general follow the original outlets. This difference in orientation between *Fundulus* and the gobies may be due in part to the fact that for the former there is usually only one correct pathway.

In a preliminary study of the factors influencing the establishment of residence in shells, Breder (in press) also suggests a topographic memory in *Bathygobius soporator* when he concludes that "entrances are memorized as to their location."

It is interesting to note that ability to retain the broad general outlines of the situation, as suggested by all of the above studies, and the dominance of this topographic memory over detailed form or color as suggested by Goldsmith (1914) are recognized among other vertebrates and primarily in birds. A bird flying in a fluid medium above the substratum lives in a habitat that bears many similarities to that of fish. Most of the theories attempting to explain the mechanisms for homing and migration in birds postulate the accumulation while in flight of the memory of a large area of the local landscape (Griffin, 1944; Thorpe, 1949; Wojtusiak, 1949). Here too the suggestion seems to be made that general topography dominates the details, for it has often been suggested by students of bird migration that the migrants follow such broad outlines as river valleys and coast lines.

The factors that normally cause gobies to jump and the adaptive significance of this behavior are still not well understood. We expected to find that drying up of the home pool would surely cause the fish to jump, but the experiment designed to test this hypothesis proved negative (protocol 8). When exposed for any length of time to the midday sun, the water in these tide pools is subject to considerable evaporation and concomitant increase in salt concentration. This we also thought might stimulate jump-

ing. Again the experiment in which sea salt was added to the water proved indecisive (protocol 8). Conversely, heavy squalls would dilute and cool the water, but when the home pool of Location V was drained and fresh water was added, only one of several gobies jumped. This one jump could easily have been stimulated by the general disturbance and not specifically by fresh water. Gobies were found regularly in pools having temperatures ranging between 35° and 39.5° C., without seeming to be disturbed. It is doubtful whether the temperature in these pools often rises much above this. Unfortunately the effect of lowering the water temperature was not investigated. Breder (1948) gives a list of regular, casual, and accidental species found in the tide pools, but he doubts (personal communication) whether any of these would be predatory on gobies. In fact the converse is more likely. Escape from birds was also considered. Terns inhabit the reefs, but they are mostly scavengers. Regular fish-eating birds are not often seen around the tide pools. Moreover, birds are more likely to pick off the fish rapidly and are not inclined to chase and prod the gobies to the point where they will jump. In addition, jumping might only make the fish more conspicuous. Captive gobies in small aquaria will often fight vigorously and are known to jump out if the tank is not covered. Breder (1948) points out that in many respects small aquaria simulate tide-pool conditions, and it may be that as the young gobies grow up the tide pools become "overcrowded," particularly when the water is greatly reduced. Nipping, chasing, and fighting may ensue, and the defeated may eventually jump out to escape. Thus, it is suggested that one factor at least in the historical development of jumping behavior of *Bathygobius soporator* may be sought in the social organization. That is, jumping may be a mechanism whereby the individuals of the species escape from one another.

SUMMARY

A preliminary field study of the jumping behavior of the tide-pool gobiid fish *Bathygobius soporator* revealed that, except for certain unusual circumstances, these fish are so well oriented before jumping that they always land safely in a neighboring pool or in the open water. The conditions are such that the fish could not possibly see the neighboring pools before leaping. Various factors that might contribute to this orientation were examined and eliminated. These included (1) orientation to the open water,

to the original outlet, or to a notch or similar configuration in the rim of the pool; (2) the position of the sun or shadows cast by the sun; (3) trial and error learning of the jumps. As a working hypothesis it is suggested that these gobies swim over the tide pools at high tide and acquire an effective memory of the general features of the topography of a limited area around the home pool which they are able to utilize when locked in their pools at low tide.

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